A Prototype Fiber Optic Spectrometer System for Limiting Instrument Self-shading Uncertainties

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Theoretical Basis

"Self shading of in-water optical instruments."
H.R. Gordon, and K. Ding, 1992
Limnol. Oceanogr, 37, 491-500

$$\hat{L}_u(\lambda) = \frac{\tilde{L}_u(\lambda)}{1-\varepsilon(\lambda)} \quad \text{and}$$

$$\varepsilon(\lambda) = 1 - e^{-k'a(\lambda)r},$$

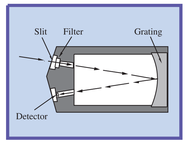
where: $\hat{L}(\lambda)$ – true value
$\tilde{L}(\lambda)$ – measured value
$k' = y/\tan\theta_{ow}$
θ_{ow} – refracted solar zenith angle
y – empirical factor ($y \sim 2$)

Accurate spectroradiometric measurements of the apparent optical properties within the marine environment over a large spectral range is an extremely challenging task. These systems must have large dynamic ranges and stray light rejections on the order of 10^{12} and 10^{-8}, respectively. An additional constraint must be considered as a result of the modeling work on the effects of instrument self-shading by H. R. Gordon and K. Ding (1992) when making these measurements in spectral regions where attenuation is dominated by absorption processes (i.e. the near-infrared due to water absorption). Experimental fiber optic shadowing measurements by D. Clark, Y. Ge and L. Koval for clear and turbid waters have demonstrated that this effect also contributes major uncertainties in these observations within turbid/eutrophic waters.

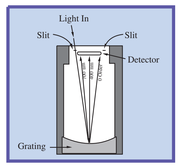
Experiment Results

Fiber Optic Spectrometer (FOS)

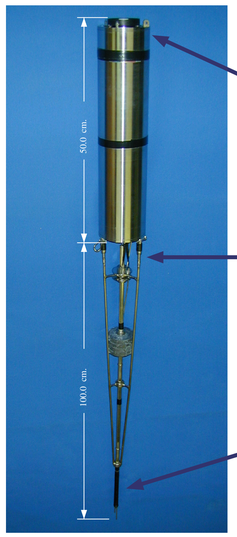
A prototype of a Fiber Optic Spectrometer (FOS) system, for the high absorption cases, has been developed in order to reduce the uncertainties associated with instrument self-shading. This system incorporates two modified American Holographic AH4000 series dual beam spectrometers (visible, f5 and near-infrared, f3.5) housed in a cylindrical, 11.5 x 50 cm, pressure case. These American Holographic dual beam spectrographs are designed to allow simultaneous dispersion of the irradiance and radiance spectra onto a 512 element Hamamatsu self-scanning diode array. Thus, allowing the system to measure the incident surface irradiance, downwelled irradiance, and upwelled radiance at nominal spectral resolutions of 5 nm from 375 to 725 nm and 10 nm from 600 to 1100 nm. The spectrometers are coupled to the radiance and irradiance collectors with 1.0 mm and 0.10 mm silica/silica glass fibers, respectively. The radiance collector fibers can be displaced 0.5 to 1.5 m from the instrument housing, via a dual optical pressure housing feed through, to further reduce shading effects. The incident surface irradiance is acquired only during the near-surface radiance measurements. The preliminary results from the marine optical experiment conducted in the Gulf of California (October 1999) for a turbid and clear water stations are presented.

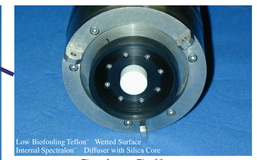


Slide view of the MD5 optical module (American Holographic) [4]

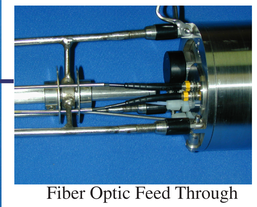


MD5 Optical schematic showing wavelength distribution over the diode array. (American Holographic) [4]





Cosine Collector



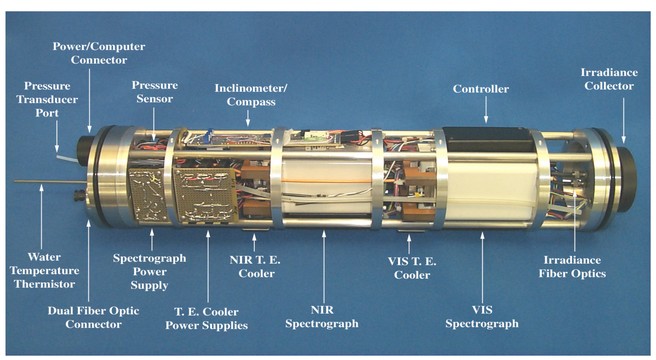
Fiber Optic Feed Through

Fiber Optic Radiance Collectors

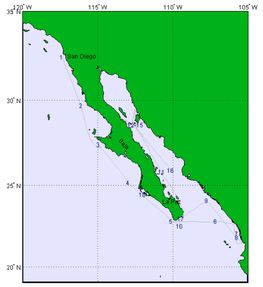
Spectrograph Specifications	VIS	NIR
Model	AH4230	AH4240
Wavelength Range	375 - 725 nm	600 - 1100 nm
Slit	50 um X 2.5 mm	100 um X 2.5 mm
Focal Length	f5	f3.5
Nominal Resolution	1.33 nm	1.56 nm
Bandpass FWHM	5 nm	10 nm

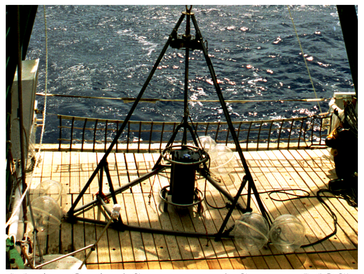
Ancillary Sensors	Range	Resolution	Accuracy	
Depth	0 to 100	0.003	0.02	Meters
VIS Detector temperature	-10 to 100	0.002	0.05	°C
NIR Detector temperature	-10 to 100	0.002	0.05	°C
Water temperature	-10 to 100	0.002	0.05	°C
Internal temperature	-40 to 85	0.031	0.5	°C
Azimuth	0 to 360	0.080	<1	Degrees
Pitch/Roll	±70	0.017	<0.02	Degrees

Dimensions		
Diameter	114	mm
Length	500	mm
Instrument weight	4.8	Kg (In water)
With frame and ballast	8.9	Kg (In water)
Self-shading	0.01	sr. with 1.0 meter Radiance fiber
	0.04	sr. with 0.5 meter Radiance fiber

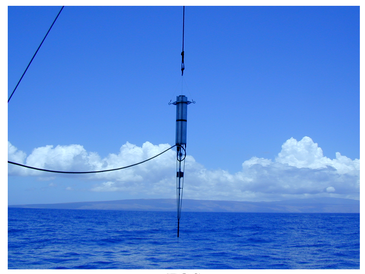


MOCE 5 Initial Observations



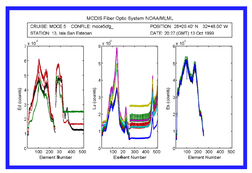


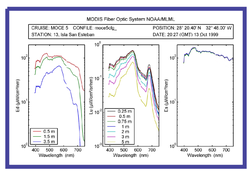
Marine Optical Spectrograph System (MOS)

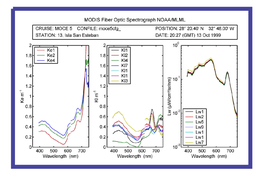


FOS

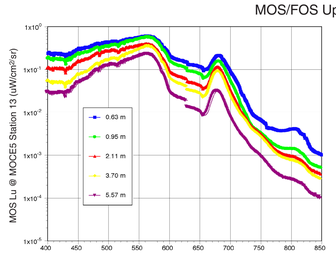
Data Processing

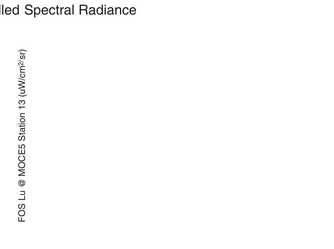


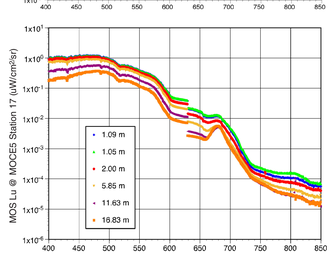


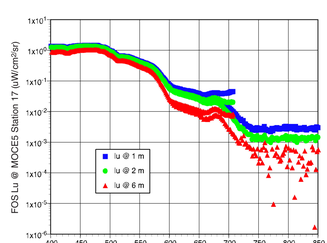


MOS/FOS Upwelled Spectral Radiance









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Reference:
3. H.R. Gordon and K, Ding, 1992. Limnol, Oceanogr, 37, 491-5000.
4. J.T. Brownigg, Design and Performance of a Miniature Dual-Beam Diode-Array Spectrometer. American Holographic, Inc.